N90-20526

# Gravity Field of the Western Weddell Sea: Comparison of Airborne Gravity and Geosat Derived Gravity

*R.E. Bell[1], J.M. Brozena[2], W.F. Haxby[1] and J.L. LaBrecque[1]*

[1]Lamont-Doherty Geological Observatory, Palisades, NY 10964
[2]Code 5110, Naval Research Laboratory, Washington, DC 20375-5000

## Introduction

Marine gravity surveying in polar regions has typically been difficult and costly, requiring expensive long range research vessels and ice-breakers. Satellite altimetry can recover the gravity field in these regions where it is unfeasible to survey with a surface vessel. Unfortunetly, the data collected by the first global altimetry mission, Seasat, was collected only during the austral winter, producing a very poor quality the gravity field for the southern oceans, particularly in the circum-Antarctic regions. The advent of high quality airborne gravity (Brozena, 1984; Brozena and Peters, 1988; Bell, 1988) and the availability of satellite altimetry data during the austral summer (Sandwell and McAdoo, 1988) has allowed us to recover a free air gravity field for most of the Weddell Sea. This paper will briefly review the derivation of the gravity field from both aircraft and satellite measurements before presenting along track comparisons and shaded relief maps of the Weddell Sea gravity field based on these two data sets.

## Airborne Collection and Reduction

The airborne gravity was collected using the Naval Research Laboratory's Airborne Gravity Surveying System. This system includes a Lacoste-Romberg air-sea gravimeter, a short pulse radar altimeter, a pressure altimeter and two GPS sets, a TI 4100, a P-code receiver and a Magnovox T-set, a CA-code receiver. To extract the geologically interesting free air anomaly ($A_{FAA}$) from the total accelerations recorded by the gravimeter ($A_M$) the position of the aircraft in three components must be well determined. The relationship between the total measured acceleration field ($A_M$) and the free air anomaly ($A_{FAA}$) is described by the equation:

$$A_M = A_{FAA} + A_{aircraft} + A_{Eotovs} + A_{Theo} + A_{FAC}$$

where $A_{aircraft}$ is the acceleration associated with the vertical motion of the aircraft, $A_{Theo}$ is the gravity on the ellipsoid, $A_{Eotovs}$ is the correction necessary for all gravity measurements made from a platform moving across a rotating earth and $A_{FAC}$ is the free air correction necessary to reduce the airborne measurement to the geoid. In contrast, to marine surveys where the maximum correction is 75 mgal, the amplitudes of these corrections far exceed the amplitudes of the gravity anomalies associated with such large features as seamounts, fracture zones and sedimentary basins (Figure 1).

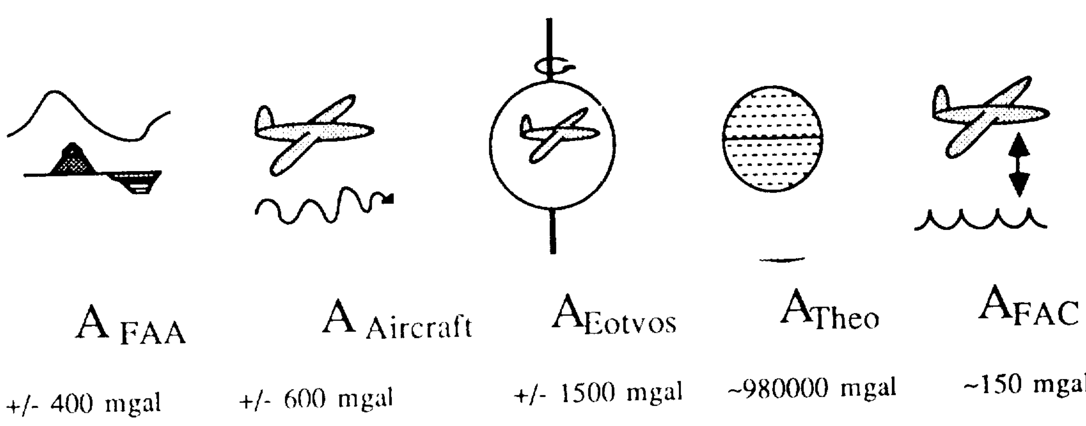


**Figure 1.** Schematic illustrating the components of the total acceleration field $A_M$ measured by a gravimeter mounted aboard an aircraft and the possible amplitude range of each component.

The GPS receivers are used to monitor the horizontal velocities and the aircraft horizontal position necessary for $A_{eotovs}$ and $A_{Theo}$ while the radar and pressure altimeters are used to monitor the aircraft's vertical position. The vertical positions measured by the altimeters were used to calculate the vertical acceleration field of the system ($A_{aircraft}$) and the free air correction ($A_{FAC}$). For the 12000 km of data collected in the 1987 field season, the pre-adjustment crossover errors were 4.59 mgal for 84 crossings and improved to 2.25 mgal after along track adjustment.

**Satellite Data Collection and Reduction**

Extracting the gravity field from the Geosat data involves first editing the individual sea surface height profiles, adjusting profiles to minimize crossover errors, gridding the data to produce a geoid and finally calculating the gravity field. Each track was edited to remove the data crossing land and regions where the $\sigma_n$ for 7 points exceeds 10 cm, a criterea which removes most of the noisy data across multi-year ice. After the tracks are edited, the repeat orbits are averaged to produce a mean profile. The crossover errors for these adjusted mean profiles are reduced to a minimum using an iterative least squares approach. Finally, gravity anomalies are calculated from the gridded altimetric geoid using Fourier transform methods.

The strength of the satellite data in the Weddell Sea is that it provides the very dense data coverage and the regular track spacing. In the central Weddell 3 to 4 orbits are averaged to produce the mean profile. However close to the limit of the satellite coverage, notably across the ice covered margin of the western Weddell, often only one orbit was available, resulting in a deterioration of the gravity field recovery.

**Merging the Airborne and Satellite Gravity Fields**

The two gravity data sets are quite complimentary as the airborne survey fills in a large hole in the satellite coverage where the altimetry was quite poor while the Geosat data provides the only ground truth available for the airborne gravity survey (Figure 2). No major offset exists between the two data sets. The two were merged so that in the extreme western and southern sections of the Weddell Sea the airborne gravity was used as in this region generally only one satellite pass was available to calculate the mean profile and the number of crossing tracks was small. In the central and northern Weddell Sea the satellite data was used in preference to the airborne data as in this region the satellite tracks are much denser than the airborne tracks. Figure 3 shows shaded relief maps of the gridded Geosat gravity field and the combined satellite and aircraft gravity field. The prominent features are the north-south trending continental margin edge effect and the regularly spaced fracture zone lineations trending northeast-southwest in the southern Weddell and northwest-southeast in the northern Weddell. An important result of this work is the dramatic relocation of this north-south trending continetal margin. Earlier bathymetric maps, based on sparse data, placed the shelf edge over 100 km to the east of the location now required by the prominent edge effect in the airborne gravity field. The strongly lineated gravity anomalies mapped in the satellite field are suggestive of major reorganization in the Weddell Sea spreading system at approximately 80 my (Haxby, 1988).

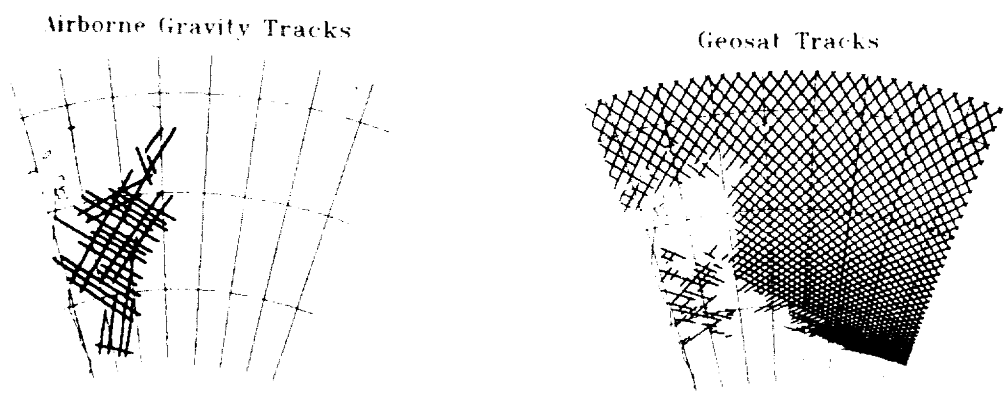


**Figure 2.** Track spacing the for 1987 airborne gravity survey (left) and for the Geosat mission (right). The limits of the map are 62°W to 23°W and 75°S to 58°S.

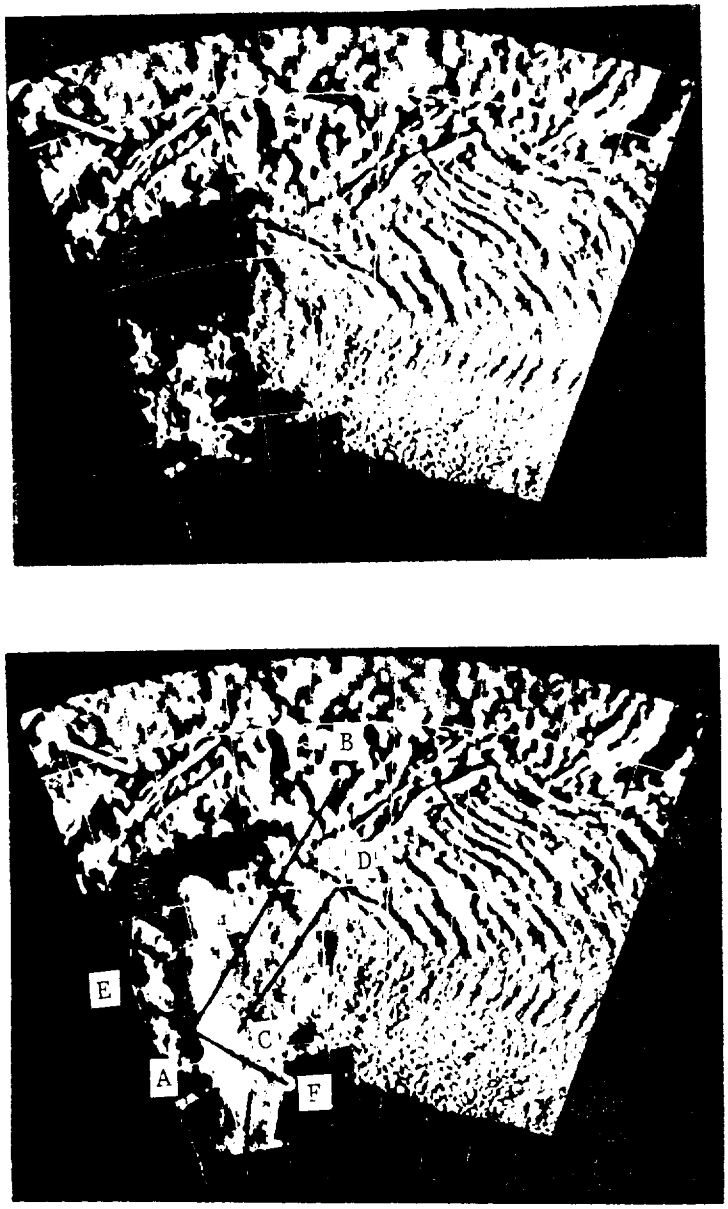


**Figure 3.** Shaded relief maps of the gravity field derived from the Geosat gridded geoid (upper) and the satellite data set merged with the gridded airborne gravity (lower). The illumination is from the east and the limits of the map are 62°W to 23°W and 75°S to 58°S. The lines on the merged image are the profiles presented in Figure 4.

In addition to revealing important structural features in the Weddell Sea, the merging of the two data sets has permitted us to document the validity of these two techniques in a region where no other gravity data exist. A series of along track comparisons are shown in Figure 4 where the solid line is the airborne data and the double line is the Geosat data resampled along the airborne flight lines. The agreement between the two data sets is remarkably good particularly along line **A-B**. Along this line the RMS difference between the two is 7.26 mgal for 723 points. Both systems recover the relatively long wavelength shelf edge anomaly and the short wavelength features (~15 km) just south of the Orkney Plateau at the northern end of the line. Line **C-D** also illustrates the agreement between these two methods across the 20 mgal step associated with an age discontinuity in the oceanic crust. The difficulty in using the satellite altimeter in regions of thick ice is clear in line **E-F** where the Geosat solution diverges from the airborne solution at the base of the shelf, a region where the ice is known to the thick.

ORIGINAL PAGE IS
OF POOR QUALITY

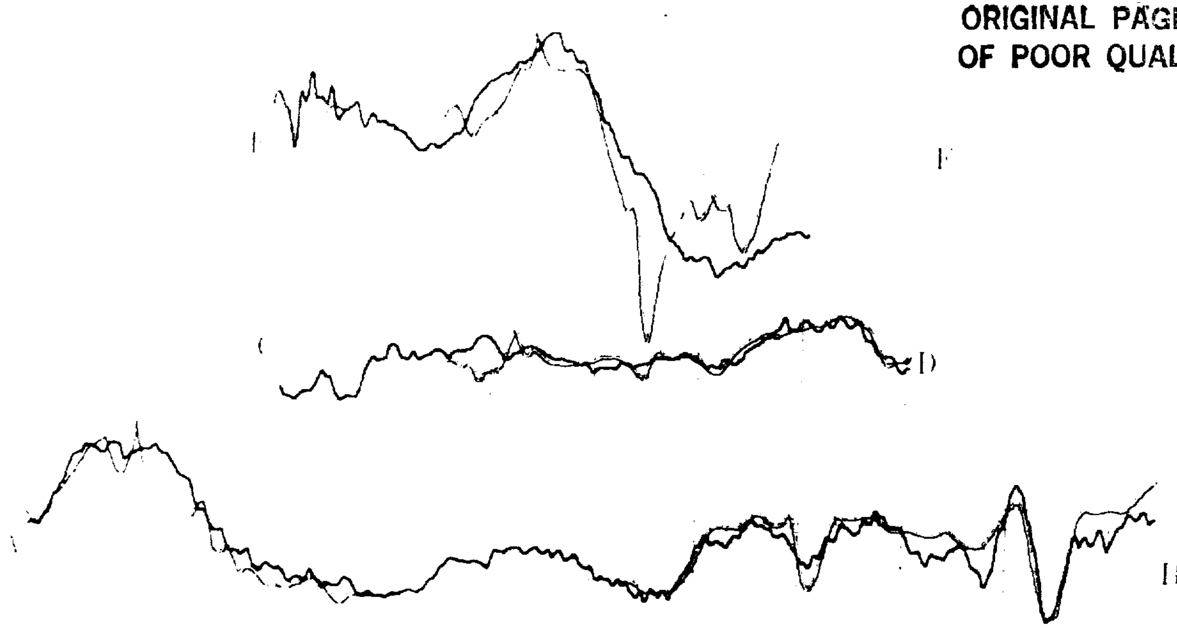

**Figure 4.** Along track comparisons of airborne gravity (solid line) and Geosat derived gravity (double line). The location of each profile is plotted on the accompanying image in Figure 3. The gridline spacing is 100 km on the horizontal axis and and 10 mgal on the vertical axis.

In conclusion, the gravity field of the Weddell Sea has been mapped using both the NRL airborne gravity system and Geosat altimetric gravity. The resultant map clearly delineates the western and southern margins of the Weddell Sea, well defined in the airborne results and large fracture zones signatures in the central Weddell, recorded by the altimetric gravity anomalies. These two data sets were compared in areas of overlap where gravity anomalies computed from gridded Geosat sea surface height were resampled along the airborne tracks. The RMS difference between the two data sets for 5483 points was 13.05 mgal with a mean of 1.60 mgal. Along track comparisons reveal that these two data sets resolve very similar wavelength features. Fracture zone signatures with widths of 15 km and amplitudes of 20 mgal are detected by both systems. The airborne system has the advantage of being able to collect data in regions of multi-year ice and focus on regions of interest while the Geosat data provides a very regular, regional coverage of the ice free region.

*Acknowledgements.* This work was supported by a grant from the National Science Foundation's Division of Polar Programs contract DPP #87-19147.

## References


Bell, R. E., High Resolution Marine and Airborne Gravity Surveys: Applications to Rifted Margins, PhD Dissertation, Columbia University, 1988.

Brozena, J.M. and M.F. Peters, An Airborne Gravity Study of Eastern North Carolina, *Geophysics*, **53**, 245 - 253, 1988.

Brozena, J.M., A Preliminary Analysis of the NRL Airborne Gravity System, *Geophysics*, **49**, 1060 - 1069, 1984.

Haxby, W.F., Organization of Oblique Sea Floor Spreading into Discrete, Uniformly Spaced Ridge Segments: Evidence from Geosat Altimeter Data in the Weddell Sea, *EOS, (Fall AGU volume)* 1988.

Sandwell, D.T. and D.C. McAdoo, Marine Gravity of the Southern Ocean and Antarctic Margin from Geosat, 93, 10389 - 10396, *Journal of Geophysical Research*, 1988.